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NOTES AND MEMORANDA

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Helminths in the Biological Control of Insect Pests

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The reduction of insect damage throughout the country is of primary importance owing to the extensive destruction to agricultural crops by these pests and four main methods are applicable in modern insect control.

Firstly, one may have recourse to the direct application of insecticides or chemicals to deter or kill the pests, although the use of insecticides is limited to a certain extent and is mainly controlled by the question of price since profits on crops at present seldom admit of much expense on insecticides.

Secondly, the agriculturist can adopt certain cultural methods whereby he endeavours, by variation in his farm practice, to place potential or actual insect pests at a continual disadvantage. Farm operations such as variations in time of sowing, crop rotation, cultivation of ground and so forth can frequently be utilised for this purpose.

Thirdly, legislation may be introduced in order to prohibit the importation of foreign insects or to restrict the movements of resident pests within the country.

Finally, the method known as " biological or natural control " in which parasites or predators, artificially bred in large numbers and introduced into the neighbourhood of the pests, may be utilised. Knowledge gained from preliminary experimental work has shown that biological control is not only effective but presents fewer difficulties and is in the long run less costly than any of the foregoing methods ; and the use of parasitic insects to combat crop pests is becoming more and more extensive. The majority of entomologists, owing to a lack of knowledge of helminthology, are apt to overlook the importance of worm parasites and although parasitism of insects by helminths is not uncommon it is seldom seriously considered as a factor in the struggle for existence. While there are but few researchers working on this aspect of biological control, work done within the past fifteen or twenty years goes to show that the incidence of worm parasitism

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and the consequent mortality is high in certain insect species. This gradual growth of knowledge about the action of parasitic worms on insect enemies may prove to be of great value in supplementing the work of predators and parasitic insects.

From one viewpoint helminths can be split into two groups. The first group contains the monoxenous forms in which the life histories are completed without the intervention of an intermediate host, the worms passing from one host animal to a similar host animal directly. The second group embraces the heteroxenous worms, which, in the majority of cases, pass from adult stages in one host animal to larval stages in quite a different kind of animal, the intermediate host, and finally return to a host animal of the first species or to a comparatively closely related animal where they develop to maturity. On occasion, two intermediate hosts may be necessary for the development of the larval stages.

Of the four classes of helminths, Cestoda, Trematoda, Acanthocephala and Nematoda, the first three are mainly heteroxenous. Among the nematodes several groups are monoxenous although two super-families, the Filaroidea and Spiruroidea, are heteroxenous, their larvae developing in blood-sucking arthropods.

Where insects act as vectors in the life cycles of heteroxenous forms they seldom suffer death as a result of the association since it is the aim of the helminth to secure nourishment without endangering the life of the host and hence its own security, and so to endeavour to reach the final or definitive host. In a great many insect vectors the adaptation of parasite to host has reached a high degree since the host is not overburdened by the presence of the worm nor is its life endangered and hence the damage done by the parasite is of no great significance.

In the monoxenous forms, however, the adaptation between parasite and host is by no means so high. The consequence is the injury, slight or severe, and even death of the insect host. In fact primary parasitism in insect pests usually results in the inhibition of normal development or in reducing fecundity or in the mortality of the host. In many instances complete sterility has been recorded.

Parasitism is recorded in almost every insect order, especially in the Orthoptera, Lepidoptera, Diptera and Coleoptera all of which contain numbers of serious pests. As a detailed discussion is impossible only a few of the more important relationships will be indicated.

In the Orthoptera numerous instances of primary parasitism have been recorded by species of *Gordius* and *Mermis*, in some cases the parasitism being of considerable economic importance. Cobb, Steiner and Christie (1927) state that *Mermis subnigrescens* Cobb, 1926, is a most important factor in the birth-rate of common eastern American species of grasshoppers. It is not unusual to find twenty-five to thirty per cent. of the grasshoppers in a given locality parasitised and frequently the percentage infestation is higher. Studies by these three researchers led them to conclude that over-infestation usually results in the premature death of both parasites and host, and they showed, experimentally, that a dose of well under fifty eggs of the parasite produces death in grasshoppers while a slightly sub-lethal dose of eggs results in all the parasites being males. Using other genera of roundworms parasitic in a fly, a tea-bug and an ant, similar results were obtained experimentally or observed in nature and they concluded that " A high degree of parasitism resulted in the parasites being all males, or practically all : a very low degree of parasitism resulted in the parasites being all females. Between these extremes there was a gradient, with mixtures of males and females occurring, the proportion of males varying with the severity of the parasitism."

According to Zwaluwenburg (1929) insects of the order Hemiptera serve, as far as is known, with but a single exception, as primary hosts of nematode worms. He states that " At least three important insect pests in this order are parasitised by mermithid worms : *Helopeltis antonii* Sign. on tea in Java, *H. theivora* Waterhouse on tea in India, and the notorious Trinidad froghopper of sugar cane, *Tomaspis saccharina* Dist."

Kaburaki and Imamura (1932) have found that a mermithid plays, beyond doubt, an important rôle in the control of leaf-hoppers which produce at times a great deal of injury to the rice plant in Japan. One species was infested to an extent of 41·3 per cent. and another up to 70·5 per cent. One or two, rarely more, nematodes were found to infest a host the insect abdomen becoming highly swollen and the leaf-hopper inactive.

Esaki and Hashimoto (1931) also reported similar findings stating that a *Mermis* species killed 70 per cent.of a leaf-hopper species in 1929 and 56 per cent. in 1930 while 43 per cent. of another species were killed in 1930.

In the Lepidoptera there are several records of primary parasitism,

nematodes of the genera *Mermis* and *Gordius* occurring most frequently. In very few cases, however, have the life histories of the parasites been adequately pursued and little information is available regarding the effects of parasitism.

In the Diptera associations between flies and nematodes are not so numerous as in some other orders of insects. The majority of records deal with intermediate host relationships although there are some interesting cases of primary host relationships.

Flint (1929) recorded a roundworm parasitising the onion maggot to an extent of 5 per cent. and Rennie (1925) recorded, from Scotland, that the well-known " leather jacket " was parasitised by a *Mermis* species which killed the grub before it could pupate.

Goodey (1930a, 1930b, 1931) found that the Frit-fly of oats was parasitised by a nematode. The distribution was not only wide in England and Wales but infected flies were also obtained from Denmark, Germany, Russia and Poland. Parasitism of the fly generally resulted in sterilisation of both sexes by preventing the development of the reproductive organs. The percentage of infection found was 4·3 in the over-wintering generation 9 to 18 in the stem generation and 2·8 to 5·3 in the panicle generation. Males were more highly infected than females and usually only one worm per fly was found.

Finally, in the Coleoptera there are numerous records of primary parasitism in beetles of economic importance both in Agriculture and Forestry.

Cobb (1928) reported that the nematode *Howardula benigna* Cobb, 1921 is apparently a control factor of great economic importance by its parasitism of three cucumber beetles of the genus *Diabrotica* in the Eastern United States. He found twenty per cent., on the average, of the beetles parasitised although as high a percentage as seventy has been recorded. Infested females are less fertile than non-infested while doubt as to diminished fecundity vanished where the female host harboured a dozen or more nematodes. Cobb estimated by count that as many as 13,000 parasite larvae were harboured in the body cavity of a single *Diabrotica vittata* (Fab.) while on several occasions twenty or more adult worms were taken from a single beetle. The two beetle sexes are infested about equally.

Glaser (1932) has conducted very interesting researches on an oxyurid parasite which infests the Japanese beetle, a pest which has assumed large

proportions and is being fought by insecticide, biological control and quarantine methods by the Government of the United States. Experimental infections of beetle grubs caused a mortality of seventy per cent. in 11·3 days, the greater the dosage the less time from infection to death. Glaser has been successful in cultivating, on a special artificial medium, the nematode through its entire life cycle, corresponding to the life history within the host, a generation developing every four or five days. Although after a time the worms lose their ability to develop upon the medium the loss is regained by a number of passages through Japanese beetle grubs. Cultivation, it is found, does not alter the pathogenicity of the nematodes for the beetles, while preliminary field experiments indicate that the parasite can be established in a region where it does not occur naturally and, when so established, produces a high mortality.

A number of parasitic associations have been reported in bark-beetles. In 1930 and 1931 I found the two *Scolytus* elm bark-beetles parasitised by a new nematode species to an extent of sixty per cent., the effect being to reduce the reproductive organs of the host, forty per cent. of those parasitised being classified as sterile. In view of the fact that it has been established that individuals of *S. scolytus* F. and possibly *S. multistriatus* Marsh. have been implicated in the spread of the Elm Disease of Holland and Belgium—a fungous disease which has spread within recent times over most of Western Europe and has been reported from twenty-seven counties in England—this record of parasitism gains in importance since the existence of biological control, as well as the usual methods adopted in forestry practice for combating the harmful effects of the beetles, both contribute towards the reduction of beetle population and in the diminution of the spread of the fungus.

It is hoped that the parasitic associations just discussed will serve to demonstrate the importance of helminths in controlling insect pests. We can, by intelligently increasing the incidence of the parasite decrease the ravages of the host. " When we come," as Cobb states, " to understand these relationships, these ' balances ' between host and parasites, doubtless we can do much toward inclining the ' balance ' in our favour. We hear more or less of organisms introduced to new areas without their enemies and parasites, and in consequence becoming frightful pests ; and we have, very painfully and slowly it seems to some of us, learned that searching for and introducing these same enemies and parasites affords

relief." Here, surely, are opportunities for co-operation between workers on parasitic helminths and workers on their insect hosts, though little advantage has been taken of this fact in the past as Zwaluwenburg observes in his statement that "the interrelationships of insects and nematodes is a subject of which most entomologists seems to have little adequate conception." Practically all the researchers on helminth parasites of insects stress the importance of worms in the biological control of pests and have thus disclosed a vast and important field for study by economic helminthologists and entomologists.

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